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CONFERENCE ON THE RESEARCH PROJECT AT

THE C. W. SHILLING AUDITORY RESEARCH CENTER

"IDENTIFYING AND TEACHING AUDITORY CUES FOR TRAVELING IN THE BLIND"

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AMERICAN FOUNDATION FOR THE BLIND, INC.
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This conference is part of a series which will contribute to a long-range research plan to be submitted to the Office of Vocational Rehabilitation and to other interested organizations.

These conferences are sponsored by the American Foundation for the Blind, The Office of Vocational Rehabilitation (Contract #800-871) and The Seeing Eye Inc. Veterans Administration has participated in one of the conferences. The Massachusetts Institute of Technology has been the host facility for all except one day of the conference series.

Proceedings of the other conferences in the mobility area are available at the American Foundation for the Blind.

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Dr. Harris opened the conference by restating the goals which had been set for the Shilling project during the proposal stage. In December 1959 the following concepts were formulated:

(1) It was thought that binaural recordings might be valuable in mobility training programs. At that time there was apparently no rehabilitation center making use of the new stereophonic technique and illusion. This stereophonic or binaural technique was beginning to be used widely in commercial operation at that time.

(2) It was further proposed to take advantage of miniaturization. Miniaturization in this case meant making a relief map of a particular area with representation of important terrain features as well as man-made objects --- buildings, fire hydrants, telephone poles, etc. Blind persons engaged in the process of mobility rehabilitation would than be able to study the relief map through the cutaneous and kinesthetic senses and at the same time study the auditory surround through the stereophonic tapes.

(3) It was originally thought that a dummy head in which microphones were implanted could be wheeled down the street on a go-cart, thus simulating a human head and auditory system. A blind subject would then try to coordinate the movements of the artificial head down the street with the movements of a miniature cart through a scale model. It was thought that he could project himself into the actual situation in this way. As the research progressed, this idea turned out to be a blind alley. The recordings were not of a quality that would permit accurate judgments as to where the dummy head was on the sidewalk. It was necessary to move the head within a foot of the building line in order for the tape listener to perceive it. Movements of several feet from the center of the sidewalk were not apparent from the tape recordings.

(4) When the head is close to the wall and the traffic noise level is high however, it is possible to secure very useful information. In addition, there is a wide variety of complex auditory cues from the surround which is captured by the tape recording equipment and may be presented to subjects to give them an idea of what it would be like to travel through the area in question. It is also possible to detect gross changes in the building line such as open areas. Among the variables influencing the effectiveness of the binaural recording is the ambient sound level at the moment the recording is made. There is a certain level at which it is possible to secure maximum information concerning nearby reflecting surfaces. At the extremes of low or high ambient noise, the ability to detect these surfaces diminishes. Under relatively low ambient noise conditions, however, it is possible to secure certain cues concerning one's surround in terms of reflecting surfaces.

(5) It was felt that a training tape should be made. In this training tape the recordings are made at a time when the traffic noises are at or near a maximum as far as their information content is concerned. There is a variety of other auditory cues as well. This 38-minute training tape is preceded by an introductory

tape excerpted from an Ampex demonstration tape. The demonstration portion was prepared to familiarize the individual with the idea of listening to a binaural recording. It includes music and sound effects. The 38-minute training tape is annotated to point out specific auditory cues. The cues are then repeated without comments so that the individual is given an opportunity to listen for them himself.

(6) It was believed that in addition to binaural recordings made under fairly high ambient noise conditions, it would be useful to experiment with self-generated sounds. Tapes will soon be made which contain no traffic or other noise. The sound the subject hears will be from his own footsteps and his own cane. This would simulate travel at night or in areas where there is virtually no vehicular or pedestrian movement.

(7) Another area which will probably be explored concerns the emission of artificial sounds. Blind persons are generally opposed to carrying sound generators since they usually attract attention. It is believed, however, that some unobtrusive sounds of high frequency and brief duration might be useful in detecting and identifying obstacles.

The comment was made that most of the recordings have been made on an Ampex two-channel tape recorder whose dynamic range is probably 45 to 50 db under the best conditions. This dynamic range is only a portion of that which occurs in the everyday auditory environment. It was then asked whether this does not limit the amount of information available from the tapes. It was agreed that this was true, that there were many subtle cues which were missed because they were below the noise level of the tape. Although high masking noise conditions cause many of these cues to be missed in life it was agreed that the effect of interposing the tape recording equipment between individual and his environment creates much more of a loss than does the real life situation. Dr. Harris pointed out that it might be possible to determine how much of the information was being lost by two experiments. One would be conducted in an anechoic chamber and the second would be on the street with the individual wearing headphones and the information would come directly from 640AA microphones, through preamplifiers, to the subject. The tape recorder in each case would be omitted from the system.

The chairman commented that it should be possible to compare the usefulness of the recordings made under fairly high ambient noise conditions with those made under low noise conditions. It might then be necessary to use volume expansion and compression techniques in order to give the listener a wider dynamic range.

(8) Dr. Harris mentioned that another of the original plans of the project was to create a head-turning tape. In this head-turning tape, a dummy head is placed by the side of the road in one of five positions with respect to the traffic flow-zero, 45 degrees right, 90 degrees right, 45 degrees left and 90 degrees left. The traffic sounds last 15 seconds, after which there is a 5-second interval of silence. The subject is asked to tell which way the head is turned. He is also required to tell whether he is sure or unsure of his decision. Results are surprisingly poor, 80% correct being a good score. When you consider that the changes of angle are on the order of 45 degrees whereas experiments by Professor Mills and others have indicated that horizontal localization is as good as one degree, it seems as though a great deal of information is being lost with the dummy head and the binaural tapes. In presenting these tapes the lows were filtered out and the high frequency energy which remained permitted individuals to obtain a higher score. Thus the lows did not seem to be particularly useful. There was also a low pass filter cut-in. It was surprising to learn that a wide band of information could be left out, yet the individual's performance did not deteriorate significantly. It may turn out that there is also little deterioration with reduced dynamic range. Presenting the information over speakers as opposed to headphones yielded no significant change in the results. Dr. Harris pointed out that it would be unfortunate if any of the tapes required speaker presentation, since rehabilitation centers do not have the special acoustically treated facilities necessary for the use of speakers.

In conclusion, Dr. Harris stated that in the beginning it was hoped a series of tapes could be made in a model village. One set of tapes was made in one area and another in a second area to determine whether generalization was possible. As of January 19th the feasibility of such generalization has not been tested. Dr. Harris went on to indicate that the goals or objectives of the project changed. Emphasis was soon placed on the preparation of training tapes. These tapes included auditory cues corresponding to a recessed store front, objects along the edge of a curb, etc. This emphasis on the wealth of auditory cues available to an adventitiously blinded person was first realized in these training tapes. Other tapes involving the detection of special cues will be prepared as the project continues into its last year. These tapes could be duplicated and copies made available to rehabilitation centers. After the adventitiously blind person listens for several hours to these tapes he should have a much better idea of what to attend to in the auditory environment.

(9) Another technique conceived of was the use of motion pictures to analyze the movements of subjects. How nearly optimum is the subject's path? What problems does he encounter along the way and how does he handle them? A grid was drawn on the sidewalk in order to determine deviation from the optimum path from starting point to travel objective.

(10) It was felt that a great deal of assistance could be obtained from expert travelers. Therefore a group of 10 expert travelers listened to the tapes, traveled through the area, took the auditory abilities test, the intelligence test and the personality inventory. Critical comments were elicited from these expert travelers. It was believed that their performance could be used as a standard for the performance of the non-expert traveler.

Dr. Harris speculated as to whether travelers might perform better in a second environment after they had received orientation and training in a first environment. If so, the technique used in presenting auditory and other information from training tapes and tactile maps would be useful and could be generalized. This would represent, in other words, the acquisition of skills which could be transferred to unfamiliar areas.

Dr. Harris stated that another major feature of the project was the determination of auditory abilities. The first logical thing to do is to give subjects an audiogram. There would be some attempt to correlate hearing acquity with traveling capability. Special auditory abilities, described later in these notes by Dr. Curtis, involved pitch discrimination, loudness discrimination, etc. Correlations between travel performance by expert travelers and the results of their various tests will be discussed by Mr. Winer. Many of the tests of personality and intelligence have not been standardized for the blind population. The two tests used in this project, however, have been standardized - the verbal scale of the WAIS Intelligence Test, and Mary Bauman's Emotional Factors Inventory.

Dr. Harris stated that based upon the results of the headturning test he felt it was desirable to go ahead and do some studies of the minimal audible angle, although this has been pursued before by Dr. A. W. Mills and others. (See Appendix A.) It seems that this requires further investigation because of its importance to the localization of sounds and specific auditory cues by the blind traveler. One technique would be to use a moving sound source with a second, stationary sound source as a reference. Dr. Harris pointed out that where there are two stationary sound sources there is discontinuity in time as you present the signals for a brief period of time and then take them away. In the case of the moving sound source there would be continuity as far as the individual is concerned in terms of his being able to determine what is going on. This is also more nearly like the situation a blind person encounters in which he is trying to track moving sound sources. The minimum audible angle for 400 cycles where there is an oscillating speaker is only six degrees. A stationary speaker was used as an acoustical reference point.

Compare this to the minimum audible angle arrived at by Professor Mills of one degree. At 20 feet, this was about 4 inches per degree or 24 inches. The tone lasted for 5 seconds. This experiment was conducted in the anechoic chamber. When you move one speaker with reference to another and you are not oscillating the second speaker, the minimum audible angle of one degree obtains. At 125 cycles, it became 8 degrees. The question was raised as to whether this experiment had been tried in a reverberant room. Dr. Harris answered that it had not, but that it could easily be designed by setting up panels in the anechoic chamber and controlling the reverberation factors. Dr. Harris said in connection with the minimum angle, they wanted to investigate the effect of intensity, the optimum patterning for the tones, etc.

Dr. Harris said he proposed to use only pure tones. He said a prediction could be made concerning a band of noise from the pure tone analysis. The temporal separation of the tones would probably be very important, Dr. Harris stated. The complexity of the tones will be investigated. Frequency glissandos was given as an example. Rapid sweeps might be made over a half-octave range. If sounds are to be generated by the individual, we should investigate what kind of sounds he should use to secure maximum localization under a variety of conditions.

Dr. Harris said that so far nothing which has been tried has improved on Mills' paradigm. The performance has not improved. Rather it has deteriorated with the experiments conducted in an anechoic chamber to date. A question was raised concerning how long the oscillation took. The answer was that it took one second to go 16 inches.

The comment was made that this experiment with the oscillating speaker involves a critical phase velocity problem. There may be a minimum phase velocity discriminable by the human under given conditions. For example, a 125 cycle tone is a rather poor one for detecting phase change. If you could move a tone of this frequency slowly enough through a 45 degree arc, the individual would not be able to tell what was happening. Low frequency tones have time characteristics that are too long to provide any amount of fine discrimination. The chairman pointed out that in real life situations, low frequency energy creates the most severe masking problems, and that this is often the most dangerous situation in which the blind traveler is involved.

Dr. Harris stated he had not thought of studying the minimum audible angle under masking noise conditions, but that this might be introduced in the experiment at a later date. The comment was made that masking noise can be a boon as well as a burden. That is, under certain conditions masking noise which can be localized can be considered useful information. When it becomes too intense or cannot be localized it then takes away information.

Dr. Harris described the dummy head. It consists of a core of balsa wood covered with 1/4 to 1/2 inch of rubber simulating the flesh of the human head. There were rudimentary pinnae molded in the rubber. Holes were drilled through the rear of the head to the ears to accept 640AA microphones. Microphone diaphragms were near the surface of the head rather than recessed. The head was mounted on a pole at about the level of the head of a standing human. The pole was mounted on a relatively noiseless go-cart. Beyer phones and an Ampex 300 series tape recorder were used. Two 90 mil tracks were used. The master tapes were made at 15 ips. Western Electro-Acoustic preamplifiers were used with 640AA's. The training tape referred to previously was demonstrated. (See Appendix B.)

The chairman pointed out that in attempting to duplicate this tape using high speed duplicators, many of the subtle cues are lost. It is not possible to use high speed commercial duplication systems to reproduce these tapes. They must be done on high quality tape recorders, with one unit being used for play and the other for record. There must be a one to one speed relationship. That is, the original cannot be played back at more than 15 ips.

The chairman added to Dr. Harris's remarks concerning concepts in the project. It was decided early in the project that a variety of pinnae should be constructed to see if any were more useful for picking up information than a duplicate of the human pinna. He said that after the conference adjourned, any member who wished to might visit United Research where they had made recordings using an artificial head with pinnae. Dr. Wayne Batteau had invited members of the conference to visit the United Research Laboratory. Dr.Harris then indicated some of the things they hope to try during the remaining time of the project. One would be to incorporate electronic switching so that microphones at the ears could present information to the opposite ear. The microphones might be built into the subject's hat. The second thing to be tried would be to introduce a delay line. Shubert found out that a 12 millisecond difference in time of arrival enabled speech to be retrieved more adequately from noise. This might work for other kinds of signal as well. A third item to explore would be the size and shape of the pinna. Dr. Harris amplified the remarks made earlier by the chairman concerning the experimentation with the pinna. He said he doesn't believe any individual would accept grotesque, elongated ears. On the other hand, pinnae might be made which would act as Helmholtz resonators to pick up very useful information in a narrow frequency range. He cited an example from the French Maritime Service where Helmholtz resonators, tuned to 60 cycles, are worn by men on watch who are listening for fog-horns. It may turn out that the optimum pinna is not acceptable. On the other hand experimentation should proceed to arrive at a variety of useful pinnae. One or more of these might be both useful and acceptable. A special pinna might be constructed which would be used in conjunction with a sound-radiating device to improve sensitivity. Other humans in the area would not notice the sounds from the device, but the blind subject with his Helmholtz resonators, covering the band of frequencies being used in the radiating source, would be able to benefit.

Dr. Curtis described those parts of the project already completed. He enumerated six items:

(1) The mobility aids scale. (See description on p. 12 ff.)

(2) The interview material. (See Appendix D.)

(3) The Primary Auditory Abilities test. This battery of tests was developed under Dr. Harris' supervision. The tests measure difference limens for frequency and intensity. The question behind these tests was, "Do people who are blind and who travel extensively have better discrimination in terms of these primary auditory abilities than blind persons who do not travel?" The blind travelers may be able to make finer judgments of auditory information. It was also felt that the better traveler in addition to having finer discriminations would also tend to use more of the available auditory information. The person who travels with a cane is depending on his own remaining senses more than a blind person who travels with a companion. This Primary Auditory Abilities test was administered to a group of ten blind persons who travel exceptionally well. The test was also given to some persons who are considered poor travelers. The latter group are not home bound but they travel only occasionally and in a familiar environment. The good travelers also navigated a designated course in Mystic, Connecticut, hereafter referred to as the mobility area. A tactile map was made of this area. There was also the training tape which was recorded with a moving cart, a dummy head, and tape recording equipment. The principal attempt here was to secure performance criteria for the good traveler. Other blind persons who were to be evaluated later would have their performance compared with this group of good travelers. The performance of the good travelers was measured in the following ways:

(1) The total time required to make a round trip through the mobility area.
(2) How well they kept to their chosen path. In some cases the blind traveler preferred to walk nearer the curb and in other cases nearer the store fronts. This in turn seemed to depend on the direction in which they were traveling through the mobility area. It was decided therefore, not to judge their performance on the basis of how closely they adhered to the center line, but rather on the basis of how closely they adhered to their own preferred path.

(3) Whether they touched obstacles with any part of their body and whether they stumbled on terrain changes.

To measure the deviations in the preferred path, ten points were chosen along the sidewalk route. A grid was then set up with six-inch intervals. As the subject walked down the street the experimenters recorded exactly where he was when he crossed each of these measuring points. The total travel time correlated positively with deviations from the preferred path, that is the higher the travel time, the more deviation from the preferred path. This correlation was significant at the 5% level.

At this point Dr. Curtis requested comments on the performance criteria. He said they were looking for better ways of measuring performance as well as a critical analysis of the methods being used. For accurately tracking the subjects, it was thought at first that a movie camera would be the ideal solution. The traveler would walk down the street and the experimenter would follow at a certain distance and a continuous movie would be made. The movie technique did not work for the following reasons:

(1) There is an alley midway along the mobility route. Cars would proceed out of the alley and block the view of the camera.
(2) Pedestrians along the way would become interested in the traverse of the blind traveler and the moving pictures that were being taken. They would get in the way of the camera, accidentally or deliberately, and thus block the view, particularly of the subjects' feet and the sidewalk markings.

One of the participants asked at this point if it were not possible to mount the camera above the street, perhaps in one of the buildings. The problem here is that there seem to be no buildings from which it is possible to view the entire travel route. In the discussion that followed, it was suggested that the camera be mounted on a tower or pole some distance from the building line. This would permit a view of the entire area. A wide angle lens would be required. It would be possible to photograph adequately from above substantial portions of the route but it was felt necessary to have check points along the entire route.

The suggestion was made that the camera be mounted on the individual. This idea had been thought of but it was felt that there might be some interference with the person's movements or with his use of the cane. Although each subject knew that his performance was being measured, his awareness that he was carrying a camera might make him self-conscious and interfere with his performance.

The problem of tracking subjects will become even more difficult as the mobility area is expanded to include greater distances. The general conclusion reached was that, if possible, a wide angle lens camera should be mounted about 50 feet above the rotary in Mystic village. The problems of distortion at distances would not interfere with gathering data because the grid on the sidewalk would be distorted equally with everything else. It still would be possible to tell precisely where the subject was. In fact, with the camera fixed, it would not be necessary to have a grid, since the dimensions of the sidewalk in the picture will not change.

Subjects traveled through the area under real traffic conditions. It generally took only 3 trips for a subject to arrive at his optimum performance. In some cases the good traveler reached a peak performance by the second trip. In general the good traveler thought the course was much too easy for him. He felt it offered no challenge or peculiar difficulties.

There appeared to be no significant correlation between the scores in the Primary Auditory Abilities Test and the performance of good travelers in Mystic.

Some persons performed well in the mobility area and not nearly as well in the Primary Auditory Abilities Test. Some of the good travelers did better in the auditory test. It was pointed out, however, that since the good travelers thought the route was easy, there was a relatively small range of performance among the subjects. In discussion, the conclusion was reached that the mobility route would have to be made more difficult if the experimenters were to discover any range of performance among the good travelers.

The question was raised as to whether any of the subjects had hearing losses or other defects. The subjects were chosen carefully to eliminate sensory defects other than blindness. The only other admissable defect was controlled diabetes. Their hearing was normal, there were no leg amputations or other physical defects. They were all totally blind to eliminate the difficulty which might be encountered with small degrees of residual vision. In the time available for the project, it was believed that we could not deal with the multiply handicapped. There was one subject, however, who got into the experiment although he had a hearing loss of 40-50 db in the upper middle and upper frequency range in one ear. It did not seem to interfere with his performance, however.

The subjects were either screened by mobility rehabilitation specialists at St. Paul's or they were graduates of the program at Hines Veterans Administration Hospital. These are two of the best rehabilitation centers in the country and it was believed that if the people who had trained these individuals thought they were good travelers, this was a sufficient reference. We then tried to determine if these people traveled regularly and extensively in unfamiliar environments using a cane. The comment was made that it might be difficult to determine from the experimental design whether a person was a good traveler or not. One of the key factors was whether he was relatively experienced or inexperienced. Originally it was thought that we could pass the subjects through the area 3 times. There would be different groups of subjects, a minimum of 16 being required. Some would hear the training tape first, some would examine the map first, etc. In other words, there would be various combinations of training and experience. Unfortunately, with the number of subjects available, it was not feasible to follow through will all combinations in this paradigm design. We have concluded that the area must be made more extensive and complicated if either good or poor travelers are to derive any benefit from training materials.

The point was made that although the emphasis of the project is on auditory cues, the experimenters are well aware that other sensory channels are important. Kinesthesis and cutaneous perception for instance, provide a great deal of useful information as to what is under foot.

Some preliminary results of the testing for primary auditory abilities was distributed among the group. (See Appendix C.)

Each of the 23 blind persons studied so far in the project, has been given an air conduction audiogram, a personal history questionnaire, the Wechsler Adult Intelligence Scale 1955, (verbal scale only) The Emotional Factors Inventory and the Primary Auditory Abilities Test. A portion of this group also received the training materials.

David Winer of the Shilling Laboratory described the Mobility Aids Scale. It was felt necessary to systematically classify blind persons as to how much assistance they require when traveling. The scale also indicates how much use they make of exterosensory cues. Mr. Winer also discusses the various tests administered to subjects at Shilling - an I. Q. test, a personality inventory and an auditory abilities test.

Mr. Winer:

"(1) The Mobility Aids Scale.

The scale is based on the notion of an increasing use of auditory cues as the traveler relies more and more on his own senses and less and less on any other variety of mobility aid. Note that some mobility aids while very efficient in assisting a traveler to get from point A to point B make it unnecessary for the traveler to exercise to the fullest his own resources. In this connection the matter of performance does not enter the picture. We are concerned simply with whether one type of mobility aid demands more or less of the traveler than another type in assessing the auditory environment. Probably the most reliable and easiest method for traveling is to go with a reasonably intelligent sighted companion. Any measure of performance would indicate that this is the optimum aid, but the companion-guided traveler has no need for attending to the sounds about him. He need not time and measure traffic flow in order to cross a street. He need pay no attention to the contours and surfaces on which he is walking, etc. In short, he need not attend to any particular extersensory cues. His companion does this for him.

"The dog-guided traveler also need not be concerned with all of the hazardous details of his immediate environment. He has almost as much freedom from such considerations as if he were with a sighted companion. He must of course use some auditory or other cues to navigate and orient himself in his immediate environment and to comprehend the dog's behavior.

"With a cane, a traveler cannot rely on information filtered to him by another intelligence. He is forced to concentrate on and act upon the information supplied to him by the mechanical extension of his arm, and most especially on the exteroceptive cues which may be present relative to hazards, other details of his immediate environment, and his goal. It seems clear that he is locomoting less efficiently, probably a good deal slower, and through a more variable route than the guided traveler. Nevertheless the cane traveler is using all auditory cues available to an extent in some cases approaching the optimum. Note that among available auditory cues are those created by the use of his own cane.

"Lastly, the individual who travels with no aid whatsoever is manifestly relying on exterosensory information. If the above line of reasoning is correct, it is justifiable to erect an ordinal scale, the extremes ranging from the minimum utilization of auditory information to the maximum utilization. The continuum would run from companion to dog to cane to no aid.

"We also felt it necessary to build into the scale the distinction between familiar and unfamiliar environments. An unfamiliar environment, for our purposes, is one in which the subject has never traveled. A familiar environment is one in which the subject has previously traveled. Many travelers use no assistance in their own homes or in trips within the immediate neighborhood, but require an aid of one sort or another in going to a new locale. In general, more is expected of the traveler in an unfamiliar environment, and he will score higher on this particular scale if he chooses to enter a new locale with a maximum utilization of exteroception.

"Up to this point, we have spoken only of the blind traveler. However, our scale must be constructed so that it is applicable to all the blind. The individual who travels only in familiar environments or does not travel at all may also now be given a position on the scale. Therefore, we must now define what we mean by traveling. Traveling means going from one place to another, usually with a purpose. Now what do we mean by not traveling? It can be said that individuals who restrict their traveling to their own home are not mobile and hence may be called home bound. For the purpose of this scale, the place in which a subject lives has great bearing on whether or not he is a traveler. The place in which a subject lives is defined by the area over which he has control. If he lives in his own home or has a private entrance in a multiple dwelling, he certainly has control over this area, that is, he usually knows where things are and if things are misplaced, generally speaking

he will be told about them. So in order to be a traveler, this type of subject must go beyond his yard. On the other hand, if an individual lives in an apartment house, or does not have a private entrance, he is considered a traveler if he even leaves his specific living quarters. So we can see that the place is which a person resides can have some effect on where he will be placed on our Mobility Aids Scale.

"As a result, the following four assumptions underlie the final form of our mobility scale. First, traveling generally indicates the necessity for a greater use of exteroceptive cues than not traveling. Second, the information obtained from a guide-type aid is usually more easily and quickly analyzed for travel purposes than auditory information. Hence, the guided traveler has more information available in a given interval of time, and his task is therefore simplified. Third, a traveler will never use less mobility assistance in an unfamiliar environment than he uses in a familiar environment, and fourth, mobility aid assistance can be ordered on a continuum from minimum utilization of auditory information to maximum utilization.

"We can now relate the four kinds of mobility aid assistance mentioned above to each kind of environment. If you look in your progress report on chapter two, page two, you will see how this is done. The figure that you see in the progress report accounts for ten positions on our Mobility Aids Scale. However, we must include five more positions, that is, the subject who uses different types of mobility aid assistance in some environments, but does not travel, say, in unfamiliar environments or the subject who does not travel in either environment. And that gives us a total of 15 positions for our total scale. Successive degrees of use of mobility aid assistance are ordered from greatest degree to least degree. In other words, the highest position on this scale that is, position number 1 will be occupied by an individual who travels in both familiar and unfamiliar environments with no assistance. The individual is relying completely on exterosensory information. The lowest position on the scale, that is, number 15, will be occupied by an individual who does not travel in either environment.

"The uses to which such a scale can be put are limited. It definitely cannot be used in any way to measure performance. Actual traveling performance may be inversely related to scale position. It is well known that a person with a dog may travel much more quickly than a person with a cane. However, for our own work, it is necessary to relate an individual's daily use of auditory cues to his mobility skills.

" (2) The I. Q. Test

The verbal scale of the WAIS was chosen to be administered to each of our subjects. The performance scale is not applicable to this investigation, because sight is required for that portion. Consequently, administering it would violate the conditions under which the WAIS was originally standardized. The purpose of giving a WAIS is to determine each subject's verbal I.Q. and then to relate it to his position on the Mobility Aids Scale. The hypothesis is that use of auditory cues, indicating reliance on one's own senses, is positively correlated with I. Q. The complete verbal scale was given, that is, information, comprehension, arithmetic, similarities, digit span and vocabulary. Although the majority of published literature to date in the area of testing blind adults has utilized the Wechsler-Bellevue Form I or Form II, we investigated the possibility of using the WAIS. We found that in a study by Cole and Weleba in 1956, 46 subjects were given both the Wechsler-Bellevue I and the WAIS alternately and successively, and the correlation between the W-B I verbal scale and the WAIS verbal scale was .87. Standardization of these two scales was also investigated. It was found that the WAIS standardization sample was national and included Negroes proportionate to the 1950 census, whereas the W-B I was standardized largely on white persons in New York State. For these reasons, we concluded that we were warranted in using the WAIS as opposed to the W-B I.

" (3) The Emotional Factors Inventory Scale, hereafter referred to as the EFI.

This is a personality inventory developed by Mary Bauman of the Personnel Research Center in Philadelphia. The scale includes material indicative of personality characteristics as well as material indicative of problems arising from blindness. The purpose of using this test is to obtain an estimate of each subject's emotional stability so that it can be correlated with his position on the Mobility Aids Scale. The hypothesis is that emotional stability, as indicated by the EFI, is highly correlated with greater use of auditory cues by the subject, as he relies more on his own senses. This questionnaire-type personality inventory consists of 170 statements which are administered to the subjects, in our case, directly by the examiner. Sometimes they store them on tape and administer them that way. The subject is asked to indicate whether he agrees or disagrees with each statement. For example, one statement is, "I am easily discouraged," and the subject may say whether for him this item is true or false. The inventory was originally standardized on 200 persons of both sexes, the degree of visual loss in the standardization group running from legal blindness through total blindness. However, new norms are now available for this inventory, based on the responses of 2200 blind individuals. The EFI is composed of eight diagnostic categories: sensitivity, somatic symptoms, social competency and interest in social contacts, attitudes of blindness, feelings of inadequacy, depression, paranoid tendencies, and validity.

"(4) The Primary Auditory Abilities Test.

"This test was developed at the Naval Medical Research Laboratory under Dr. Harris, and has been administered to each of our subjects. The specific names of the tests are : Pitch Constants, Frequency Modulation, Amplitude Modulation, Harvard Loudness, DI Constants, and Quantal DI. Each of the tests was stored on tape and given over earphones in a random order to each subject. All but one of the tests, the Harvard Loudness, consist of 160 paired tones, to which the subject must respond in one of several ways. Tests are subdivided into 10 runs of 16 paired tones each. Due to a time limitation, we are able to administer only 7 runs to each subject. Also built into each test were eight levels of difficulty of the paired tones. That is, discrimination between a pair of tones becomes increasingly difficult. Each of the items on the Harvard Loudness test consists of one band of noise rather than a pair of tones as on the other tests. We first scored the number of correct responses for each subject, and then we plotted these correct responses as percentages against the eight levels of difficulty. We then drew a graph of each subject, and we are in the process of determining his DL or difference limen for each of these tests.

"The Pitch Constants test is a test of pitch memory. The tone is recorded at 1 KC and the subject is asked to judge whether the second tone in each pair is higher or lower than the first tone. The Frequency Modulation test is a test of pitch modulation. Tones are also recorded at 1 KC and the subject judges whether the pitch modulation is in the first or the second tone of each pair. The Amplitude Modulation test is a test of discrimination of pure tone loudness. The subject judges whether the first or second tone is wavering. The Harvard Loudness tests are tests of broad band loudness discrimination. The subject judges whether the second half of each noise is louder or softer than the first half. The DI Constants test is a test of pure tone loudness. These are also recorded at 1 KC and the subject is asked to judge whether the second tone is louder or softer than the first tone in each pair. The Quantal DI test is also a test of pure tone loudness, also recorded at 1 KC.

"There are two purposes in administering the Primary Auditory Abilities Test. One is to determine if the blind as a group differ from sighted people on the performance of this test, and the other is to determine if those who rank low on our mobility aids scale, that is, those who make more use of their own senses, perform better on an auditory ability test, than those who rank higher. Now for the results.

"To date, I have been concerned primarily with a correlational analysis of the data. All correlations performed were Spearman-Rho. The first set of correlations tested the hypothesis that the lower the individual is on the mobility scale, that is, the more he makes use of his own senses, the better he will perform on the Primary Auditory Abilities test. We performed six separate correlations, and we found significant correlations between the Mobility Aids Scale and Amplitude Modulation, DI Constants and Quantal DI. The correlations between the Mobility Aids Scale and Amplitude Modulation was significant at the 5% level. The other two correlations were significant at the 1% level. It is interesting to note that all three of the significant correlations were with the pure tone loudness test. The next correlations we did were between the Mobility Aids Scale and I.Q. to test the hypothesis that the more intelligent person uses less mobility aid assistance. With data from 19 subjects, a correlation of .49 was found which is significant between the 5% and 1% levels. We have also correlated the Mobility Aids Scale with the 8 categories on the Emotional Factors Inventory. The hypothesis is that emotional stability, as indicated by the EFI, is highly correlated with greater use of auditory cues by the subject as he relies more on his own senses. We find that the Mobility Aids Scale correlates with four of the categories at the 1% level and three of the categories at the 5% level. The only category that does not correlate significantly is the validity category and this is a correlation of almost 0. These correlations were expected. We did expect that the more stable an individual is the less he would depend on mobility aid assistance. We also correlated I.Q. with the six primary auditory abilities tests. The hypothesis is that I.Q. and performance on the PAA are positively correlated. We have found that I. Q. correlates at the 1% level with Amplitude Modulation and DI constants and at the 5% level with the Harvard Loudness. As with the Mobility Aids Scale, we find I.Q. correlates only with tests of loudness.

"Our next hypothesis was that the more emotionally stable an individual is, as indicated by the EFI, the better he will perform on the PAA test that we administered. We thought at first that this was a logical hypothesis since an extremely nervous or tense individual might not be able to fully concentrate on the test. Our hypotheses were not substantiated as frequently as we had expected. First, the Pitch Constants test does not correlate with any of the seven categories of the EFI. Consequently our null hypothesis can not be rejected and we must say that there is no relation between emotional stability and the performance on this particular test of pitch memory. Secondly, the frequency modulation test correlates significantly at the 1% level with the categories of Feelings of Inadequacy and Paranoid Tendencies and they correlate significantly at the 5% level with the Attitudes of Blindness. Thirdly, the amplitude modulation test correlates significantly with six of the seven EFI categories. I'm using only seven of the EFI categories, omitting Validity. The amplitude Modulation test correlates significantly with six of the seven, five being significant at the 1% level and one being significant at the 5% level. Fourth, the Harvard Loudness test correlates significantly at the 1% level with all categories except Somatic Symptoms. The correlations in this group substantiate the hypothesis better than any other set of correlations involving the EFI and the PAA. Fifth, the DL Constants correlates significantly at the 5% level with Attitudes Toward Blindness, Paranoid Tendencies and Sensitivity, and at the 1% level with Social Competency and Somatic Symptoms. And lastly, the Quantal DL test correlates significantly at the 1% level only with Sensitivity and Somatic Symptoms.

"The last set of correlations involves I.Q.and the seven categories on the EFI. The hypothesis is that intelligence, as measured by the verbal scale of the WAIS, is positively related to emotional stability as indicated by the EFI. We found significant correlations with all seven categories, five being significant at the 1% level and two being significant at the 5% level.

"By and large, the subjects who have come up to New London, Connecticut are expert travelers, and those we have tested in New York are almost completely homebound. They go out very seldom and then only with a companion.

"We did a few signifcant difference tests between those who rank low and those who rank high on the mobility aids scale and found no significant difference in I.Q. between the two groups. We next combined scores on all six Primary Auditory Abilities tests and found a significant difference between the two groups at the 1% level. Those who use less mobility aid assistance and who make more use of their own senses, do score higher on the PAA test. However, when computed separately, only two of the six tests showed significant differences. This may very well be a result of the small N (number of subjects). Our N ranged only from about 8 to 14. We next attempted to find significant differences between our two groups on the EFI. On only one scale, the Social Competency scale, was there a difference, significant at the 1% level. The Sensitivity scale, Inadequacy scale and Attitude scale were significant at the 5% level. This completes our initial findings."

At this point, tape-recorded examples of each part of the Primary Auditory Abilities test were played for the group. Each part of the test consists of 160 paired items, 10 runs of 16 items each. Dr. Harris remarked that administering the entire battery to servicemen required two days. Mr. Winer stated that because of a time limitation only seven runs (112 items) had been administered to each blind subject.

At the luncheon meeting, a variety of topics was discussed, many questions were asked, and a number of concrete suggestions offered. Following is a summary of the main discussion points.

Several comments were made in connection with the Shilling training tape. Some persons who have listened to the tape seem to have achieved good externalization and for others, the sounds seem to remain in the head. Also, some people do not detect sufficient similarity between the tape and the actual traffic situation. Miss Farrar, for example, who listened to an early version of the training tape, commented that her reaction to the mobility area was completely different from the impression she had gained from the tape. Dr. Curtis remarked that some of the blind-folded sighted subjects who received this taped training material performed more poorly in every respect than those who received no training at all. Apparently their attempts to visualize the area were misleading.

In connection with improving the tapes, the question of head movement arose several times. When listening to a binaural tape over headphones, the listener is often tempted to move his head as a natural part of the process of localizing sound. Dr. Harris suggested that it might help if the dummy head used for making these tapes was given an automatic shake of a few degrees every two seconds or so. Dr. Mills remarked that the one problem for which head movement is crucial is in resolving front/back confusions. In listening to a binaural tape made with an artificial head, however, this confusion remains unresolved if the listener does not know whether the head was turned left or right.

The question of speakers vs. headphones was also discussed. The chairman remarked that he prefers listening to the traffic tapes through speakers since, although his ability to localize does not improve, the sound does seem to be more externalized. He asked if there were not some material which might better be presented over speakers than headphones. Dr. Harris commented that speakers provide a bass boost, which is an acoustic advantage, but that he does not have sufficient information to answer the question of whether the stereophonic illusion is so enhanced by the use of speakers that headphones can be obviated. Headmounted speakers were suggested as a possibility, but unfortunately these speakers would not transmit the low frequencies that larger speakers do.

There was considerable discussion of the Primary Auditory Abilities test and several suggestions were offered for other tests which might be valuable in assessing auditory ability. Dr. Curtis began by outlining plans to develop three additional tests which, unlike the PAA, would be tests of binaural ability. First, a test to measure interaural time difference threshold; second, a measurement of interaural intensity difference threshold; and third, a test of signal detection ability, that is, retreival of a signal from various kinds of noise. Such tests might prove to correlate better with mobility capability. Dr. Mills asked if it was planned to use zero time and intensity differences, or whether the subject would be asked to discriminate between larger and smaller differences, both non-zero. Dr. Curtis replied that a graduate student at Western Reserve University had found these to be different functions and that consequently they would have to be tested separately.

Other possibilities were discussed briefly, such as reverberation tests, inter-aural phase at low frequencies and musical tests, e.g. discriminations of timbre, rhythm, etc. There was a feeling in the group that the tests should include sounds other than pure tones and white noise. The environment is which we move contains far more complex sounds than this and tests using such complex sounds might provide a more realistic evaluation of auditory ability.

Dr. Curtis described the design of some experiments to assess the effect of head movements, and of interposing headphones and/or a tape recorder between the sound and the listener. In one experiment, a subject will have microphones mounted on his head and will also wear headphones. In this way he will receive the benefit of his own head movements. His performance in this situation will be compared to his performance listening directly to the sound. Thus the effect of headphones can be assessed. Secondly, his performance while wearing microphones and headphones will be compared to his performance listening to sound through microphones mounted on an artificial head. In this way the effect of head movements can be assessed. Lastly, his performance listening over phones versus listening over phones through tape will assess the effect of the tape machine.

The discussion concluded sufficiently early to permit a majority of the participants to visit United Research Corporation at the invitation of Dr. Wayne Batteau. The purpose of the trip was to demonstrate the effect of artificial pinna similar to those of the human on "front-back confusion" and the localization in space of specific sounds.

There were two kinds of demonstrations: Dr. Batteau walked around a dummy head with artificial pinna and small condenser microphones implanted. The listener wore headphones. Each human ear received a signal which originated at the respective ear of the dummy head.

The second demonstration was on tape. A two-channel tape recorder was used to record signals from two condenser microphones. In the first series the two microphones were separated in space approximately the interaural distance. In the second series, a dummy head and artificial pinna were used.

The "front-back confusion" was resolved under conditions in which the complex sound source was moving and there were high intensity, high frequency components. The recordings were also made in highly reverberant rooms.

APPENDIX A

DETERMINATIONS OF THE MINIMUM ANGLE

The C. W. Shilling Auditory Research Center has made determinations of the minimum audible angle by three separate methods. The same four experienced subjects were used in each experiment.

1) The first experiment was conducted in a cubic anechoic room, 32½ feet on a side, echo-free above 75 cps. The subject sat facing two University tri-axial speakers placed in line, one above the other, on the zero azimuth. This is a feasible arrangement, since the ear is relatively insensitive to the vertical dimension. The stimulus was turned on in the bottom speaker for three seconds, off for one-half second, then on in the top speaker for three seconds, and turned off. Each tone had a 40 ms rise time.

The subject was blindfolded. While a burst of noise on the bottom speaker masked the sound occasioned by repositioning the top speaker, the latter was moved a certain distance left or right on its aluminum track. The subject was then forced to guess whether the top speaker was left or right of zero azimuth. The lateral shift of the speaker was then gradually reduced on successive trials until the subject's correct responses were reduced from 100% to 50%. A curve was then drawn relating per cent correct response to angle in degrees, and the 75% point computed. This point is the threshold or minimum audible angle. It was computed for frequencies of 125, 200, 400, 800, 1250, 1600, 3200 and 6400 cps. Each of the frequencies represented was selected for a particular reason. For example, 1600 cps was used because this is the frequency Dr. A. W. Mills found to yield unusually poor results. The lower frequencies were added in an attempt to show the effect of phase. Above 6400 cps the wave length is so short that directionality becomes a rather erratic feature.

The data from this first experiment indicate a minimum audible angle of about one degree up through 1000 cps. It rises at 1250 and 1600 cps to about 2 or 2¼ degrees, drops off at 3200 cps and rises again at 6400 cps. This is a common pattern followed by all subjects with only minor exceptions. Note that the rise at 1600 cps duplicates almost exactly what Dr. Mills found with an experiment of similar design but using one speaker instead of two.

2) The second experiment employed a visual zero. A vertical wand was placed at the zero azimuth, behind which was placed a single movable speaker, concealed by an opaque but acoustically transparent cloth. For a three-second on-time, subjects were required to judge whether the speaker was positioned to the left or the right of the visual zero. In this experiment too, there was a deterioration in angle discrimination at 1600 cps. Surprisingly enough, however, the visual zero provided more acute thresholds than the acoustical zero at all frequencies except 3200 cps.

3) In the third experiment the speaker was swung on a long pendulum. It was allowed to oscillate for each trial for five seconds, during which time the tone was turned on. The arc through which the pendulum swung was gradually increased in steps of one degree while the subject judged, during the five-second tone, whether the sound source was stationary or moving. The arc at which the subject judged correctly 75% of the time was taken as the minimum audible angle. Thresholds were most acute at 1600 cps. At lower frequencies the ear is apparently much less sensitive. At 125 cps, for example, a movement of as much as eight degrees was often necessary for the subject to detect the movement.

Two other experiments have been proposed and will be pursued in the near future:

1) One is an acoustic tracking experiment in which the subject by means of a joy stick attempts to move one speaker into proximity with another speaker which is under the control of the experimenter. In this and other experiments we expect to learn something of the contribution of head movements to localization; heads will be fixed stationary with biting boards, allowed to move naturally, or have certain movements forced on them, while the subject is undergoing tests for the minimum audible angle.

2) The second experiment involves inserting microphones fitted with probe tubes into the entrance to the ear canal, and the use of a dummy head with interchangeable pinnae. Our purpose here is to learn something of the effect of the shape of the head and of the pinna itself.

APPENDIX B

At the beginning of the tape, a 30-second 1000 cps pure tone at -10 VU is presented for calibrating the playback equipment. The next eight minutes consist of a history of recording, accompanied by musical selections and sound effects. The purpose of this history is to familiarize the listener with binaural reproduction and allow him to adapt to listening with headphones--both novel experiences for many.

After 30 seconds of silence and another 30 -second 1000 cps pure tone, the 28-minute training tape begins. In the first section, common auto and street sounds are pointed out by the commentator, e.g. sounds of car starting, door slamming, hammering sounds emanating from a filling station, etc. The recording is then repeated without commentary.

In the second section are heard both traffic sounds and sidewalk sounds, such as squealing air brakes, a baby stroller passing on the sidewalk, etc. Once again, the recording is repeated without commentary.

The third section, in addition to other new sounds, contains the sound of a heavy trailer truck. Before the recording is repeated, the listener is asked to notice the echo of this truck from the adjacent building wall.

In the fourth section, the recording equipment is turned 180 degrees so that the traffic sounds and their echoes are transposed. Next, recordings were made with the equipment placed one foot and twenty feet away from the building line in order to show the difference in echoes.

In the fifth section, the recording apparatus was moved along the side-walk for a distance of a block and then back again. The recording was repeated without commentary. The listener is asked to notice particularly the open area in the middle of the block where the building line recedes and where echoes, for all practical purposes, disappear.

APPENDIX C

TABLE I

		M.A.S.	N
P.A.A.	P.C.	-.0262	12
	F.M.	.5394	10
	A.M.	.4660*	18
	H.L.	.5879	10
	D.L.C.	.6744**	18
	Q.D.L.	.6484**	14

*Sig. at 5% level.
**Sig. at 1% level.

TABLE II

		M.A.S.
E.F.I.	S.	.5252**
	S.S.	.4066*
	S.C.	.5899**
	P.T.	.5054**
	I.	.4380*
	D.	.4684*
	A.T.B.	.6351**
	V.	-.0766

N=23

*Sig. at 5% level.
**Sig. at 1% level.

TABLE III

		I.Q.	N
P.A.A.	P.C.	.4212	10
	F.M.	.5000	8
	A.M.	.6390**	16
	H.L.	.7798*	8
	D.L.C.	.6331**	16
	Q.D.L.	.2605	12

*Sig. at 5% level.
**Sig. at 1% level.

TABLE IV

		P.C.	F.M.	A.M.	H. L.	D.L.C.	Q.D.L
E.F.I.	S.	.1608	.4243	.6610**	.7773**	.5495*	.5088*
	S.S.	-.1468	.2515	.5885**	.5030	.6450**	.4594*
	S.C.	-.0454	.5424	.3793	.7758**	.5939**	.1484
	F.T.	.3584	.6152*	.6063**	.6212**	.4613*	.3462
	I.	.1608	.6091*	.5387*	.7515**	.1770	.2462
	D.	.4581	.3152	.6146**	.8121**	.2962	.3615
	A.T.B.	.4108	.7606**	.7255**	.8909**	.4453*	.2725
	V.	-.3252	-.7757**	.0286	-.6363*	.0888	-.0912
	N=	12	10	18	10	18	14

* Sig. at 5% level.
** Sig. at 1% level.

TABLE V

		I.Q.
E.F.I.	S.	.5635**
	S.S.	.5947**
	S.C.	.5056*
	P.T.	.6079**
	I.	.5389**
	D.	.4808*
	A.T.B.	.7541**
	V.	-.3509

N=20

KEY:
M.A.S. - Mobility Aids Scale
P.A.A. - Primary Auditory Abilities
P.C. - Pitch Constants
F.M. - Frequency Modulation
A.M. - Amplitude Modulation
H.L. - Harvard Loudness
D.L.C. - Difference Limen Constants
Q.D.L. - Quantal Difference Limen
E.F.I. - Emotional Factors Inventory
S. - Sensitivity
S.S. - Somatic Symptoms
S.C. - Social Competency
P.T. - Paranoid Tendencies
I. - Feelings of Inadequacy
D. - Depression
A.T.B. - Attitudes toward Blindness
V. - Validity

APPENDIX D

HISTORY FORM

1. Name (Last, First, Middle)

2. Examiner | 3. Date

4. Referred by | 5. Sex

6. Maiden Name if Married

7. Date of Birth | 8. Place of Birth (City, State)

9. Present Address (Street, City, State) | 10. Phone No.

11. Past Addresses (Street, City, State)

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

12a. Were you ever in the Armed Forces

12b. Branch of Service

Army________ Navy________ Air Force_______ Marines______ Coast Guard______ Other____

13. Rank________________ Serial No.__________________ VA Claim No.____________________

14. EDUCATION	B/S	NAME	GRADE COMPLETED	LOCATION
Grammar				
High School				
College				
Technical Training				

Comments:

TRAVEL TRAINING

15a Did you ever have any travel training

15b. What types of training did you have

15c. Do you feel that the training has helped you

Comments

16. BLINDNESS

a. Age at which totally blind

b. Cause of blindness

c. Sudden Gradual

d. Treatment

e. Examining Physician Location

Comments

17. Determination of Mobility Competency

A. Assistance

1. Do you ever go away from the place in which you live

2. If yes, do you ever go alone or do you always go with somebody else

3. When you go alone do you use anything to help you such as a cane, dog, etc.

4. If (1) is yes, during the last year did you go anywhere that you have never been before

5. If (4) is yes, did you go alone or with somebody else

6. When you went alone, did you use anything to help you such as a cane, dog, etc.

17. (Cont'd)

B. Subject's Position on Mobility Scale

	Familiar	Unfamiliar
none	________	________
cane	________	________
dog	________	________
companion	________	________

C. Numerical Position on Mobility Scale ________

Comments

18.

I. Q.

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19 EFI SCORES

1. Sensitivity ________
2. Somatic Symptoms ________
3. Social Competency ________
4. Paranoid Tendencies ________
5. Inadequacy ________
6. Depression ________
7. Attitudes Toward Blindness ________
8. Validation ________
